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Finnish Transport and Communications Agency

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Arctic Challenge project's final results

Ilkka Kotilainen
Project Manager
Finnish Transport and Communications Agency Traficom
Talvitiepäivät, Tampere
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Co-financed by the European Union
Connecting Europe Facility

Problems for automated vehicle sensors and positioning

- Snow
- Ice
- Heavy rain
- Sand
- Dust
- Fog
- Norther latitudes
- Aurora Borealis

Pictures: Wikimedia Commons, Risto Kulmala and Norwegian Public Road Administration

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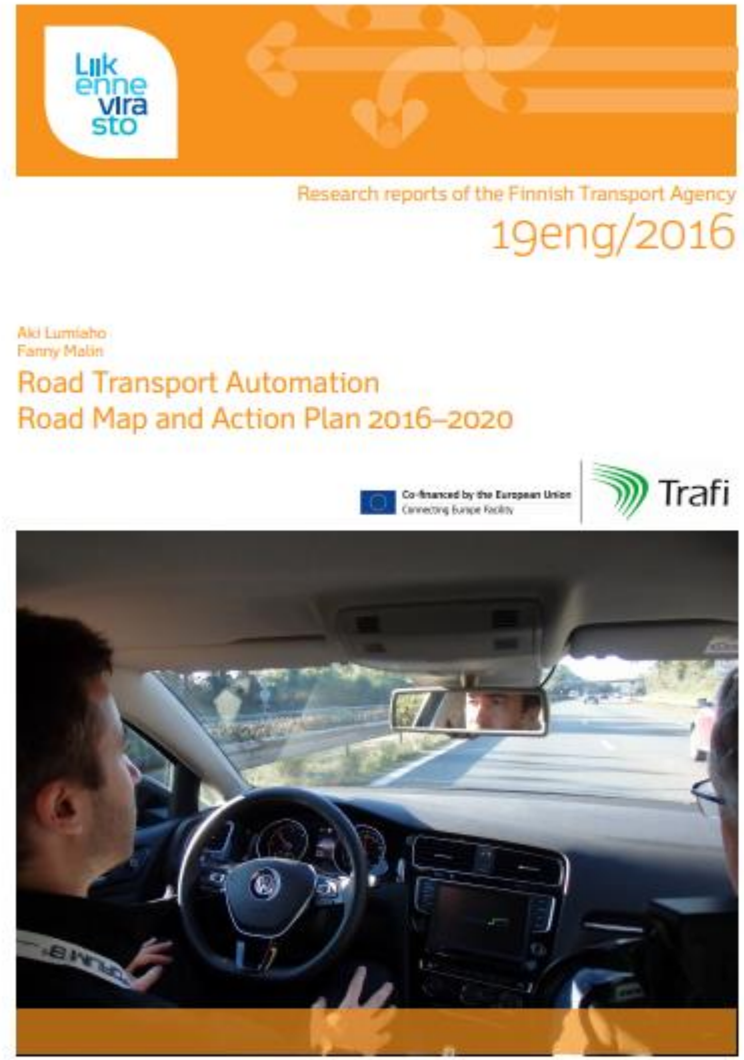
Background

- Advance of road transport automation development and possibilities in Finland and internationally

- Road Transport Automation Road Map and Action Plan 2016–2020

- Study of road transport automation and intelligent infrastructure in north arctic conditions



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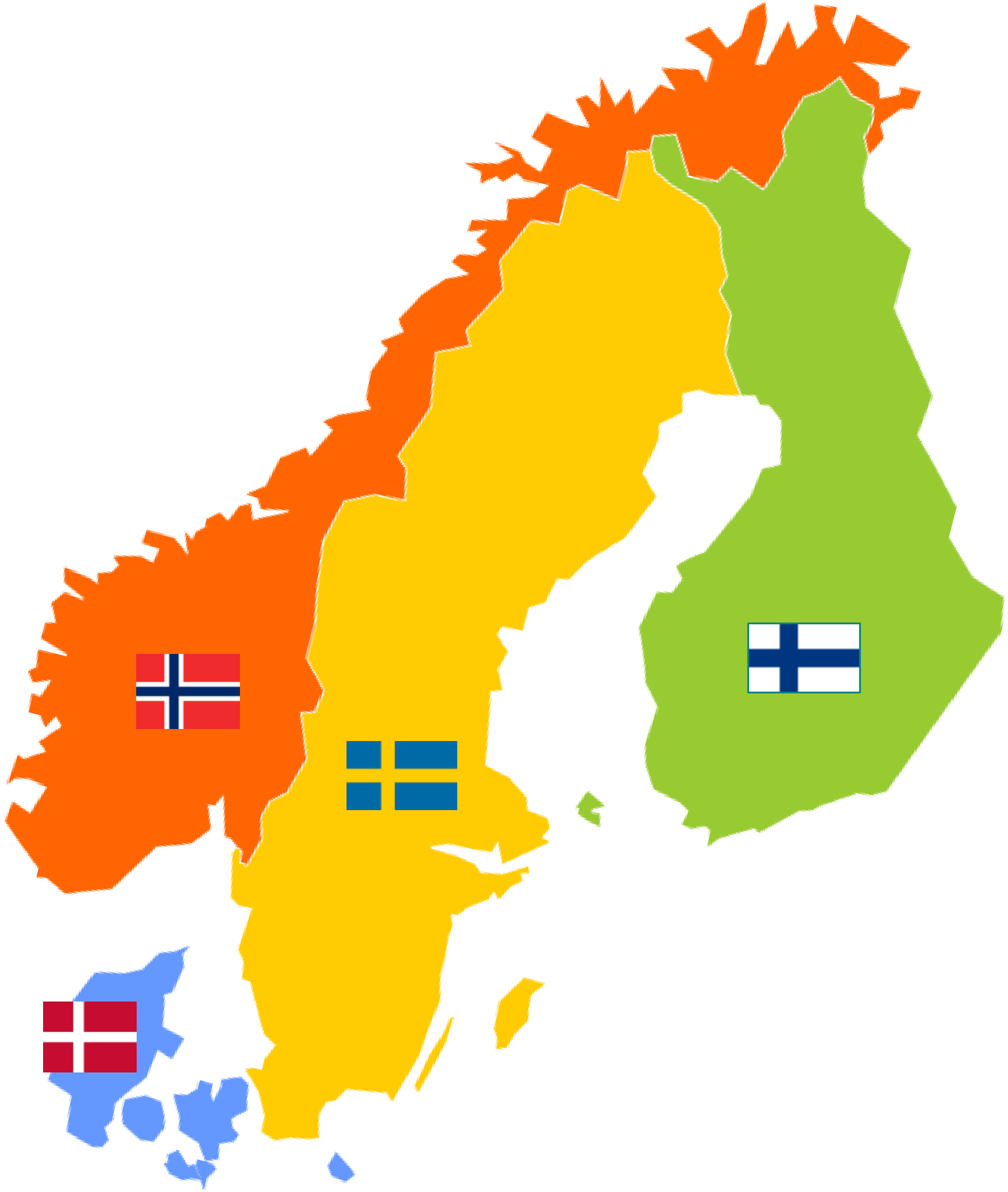
Finnish NordicWay2 projects

- NordicWay2 pilots 2017-2020
- Aim to enhance road transport safety and flow
  - C-ITS pilot: C-ITS Day 1 and 1.5 messages and European interoperability (C-Roads)
  - Arctic Challenge: support infrastructure readiness for connected and automated driving
- NordicWay2 budget 18,9 M€
  - Finnish budget 5,6 M€, which of Arctic Challenge 3,5 M€
  - European Commission EU CEF funded 50 %



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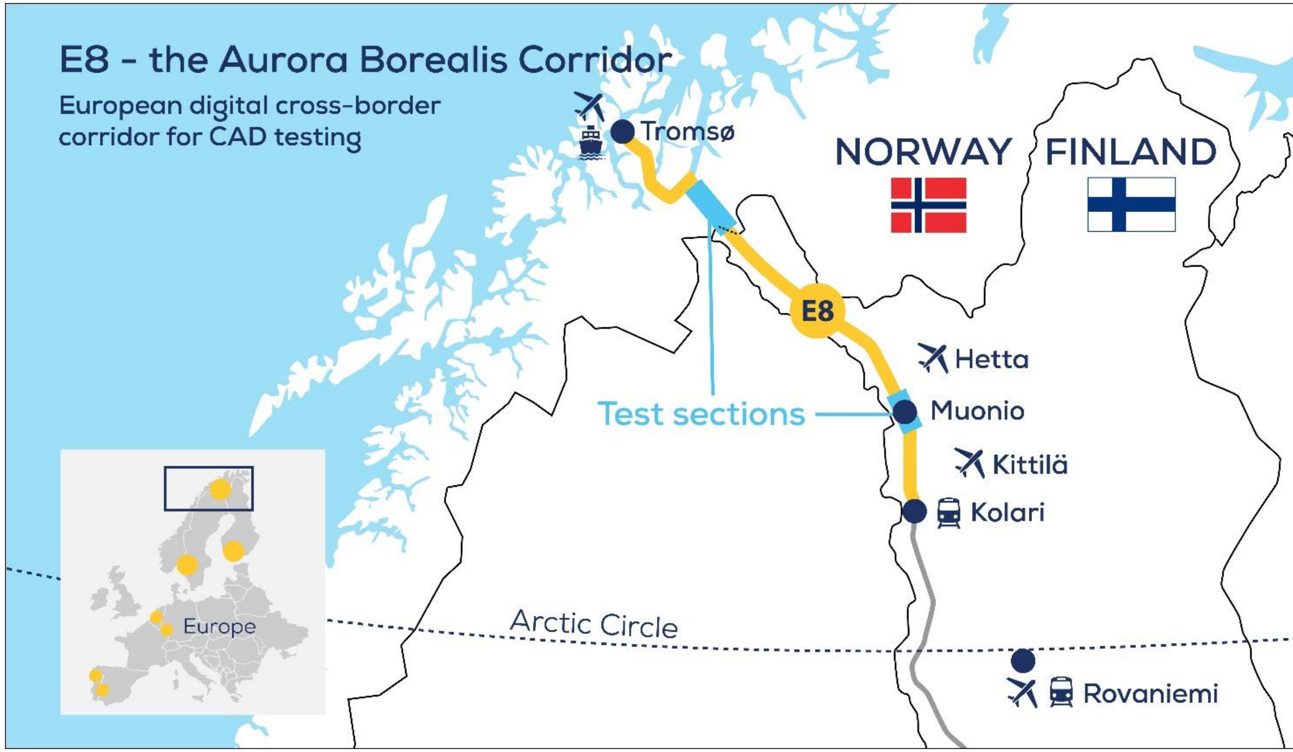
Finnish pilot 1 – The Arctic Challenge: Automated driving in snowy and icy arctic conditions

- Objective: infrastructure for CAD in arctic conditions: landmarks, positioning, hybrid C-ITS and vehicle remote control using cellular
- Location: E8 (road 21) Aurora-Borealis corridor and 10 km test section for automation
- Budget: 3,5 million euros



Arctic Challenge studies

1. **Posts and poles for guidance and positioning**: What landmarks, such as delineators and reflective posts, or snow poles and plot access marks, support automated driving? Where should these be located? What should they be like?
2. **C-ITS hybrid communication:** How could the C-ITS Day 1 hybrid services improving traffic flow and safety be implemented on the main road 21 and Highway E8 Aurora Borealis Corridor between Kolari, Finland and Tromso, Norway, and what is their technical operability? What Day 1 services should be implemented in the Aurora Borealis Corridor?
3. **Communication infrastructure and remote driving**: How does the remote control and monitoring of vehicles work in 4G and in the first stage of the 5G network in good/poor weather and road conditions? What minimum requirements should the communications network meet to enable remote control of automated vehicles?
4. **Positioning of vehicle**: In what way and how accurately could a vehicle be positioned to fulfil the needs of automated driving at northern latitudes where no edge markings or roads can be recognised? How can different methods be applied to special locations and situations, such as blind spots or glare?

Three Arctic Challenge coalitions – 15 companies

- Lapland university of Applied Sciences and Roadscanners
- Sensible 4, Metropolia Ammattikorkeakoulu, Finnish Meteorological Institute, Sharpeye Systems, MHR Consulting, F-Secure, Solidpotato and Nodeon
- VTT Technical Research Centre of Finland, Infotripla, Indagon and Dynniq

Test fests

	Test fest 1	*Test fest 2*	*Test fest 3*
	15.-19. January 2018	*1.-5. October 2018*	March, April and June 2019

Studies:

1. Posts and poles for guidance and positioning
2. C-ITS hybrid communication – Safety Related Traffic Information
3. Communication infrastructure
4. Positioning of vehicle

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1. Posts and poles for guidance and positioning: passive

What landmarks, such as delineators and reflective posts, or snow poles and plot access marks, support automated driving? Where should these be located? What should they be like?

ROADSCANNERS

LAPIN AMK
Lapland University of Applied Sciences

Material: Chris Händel, Roadscanners,
chris.handel@roadscanners.com

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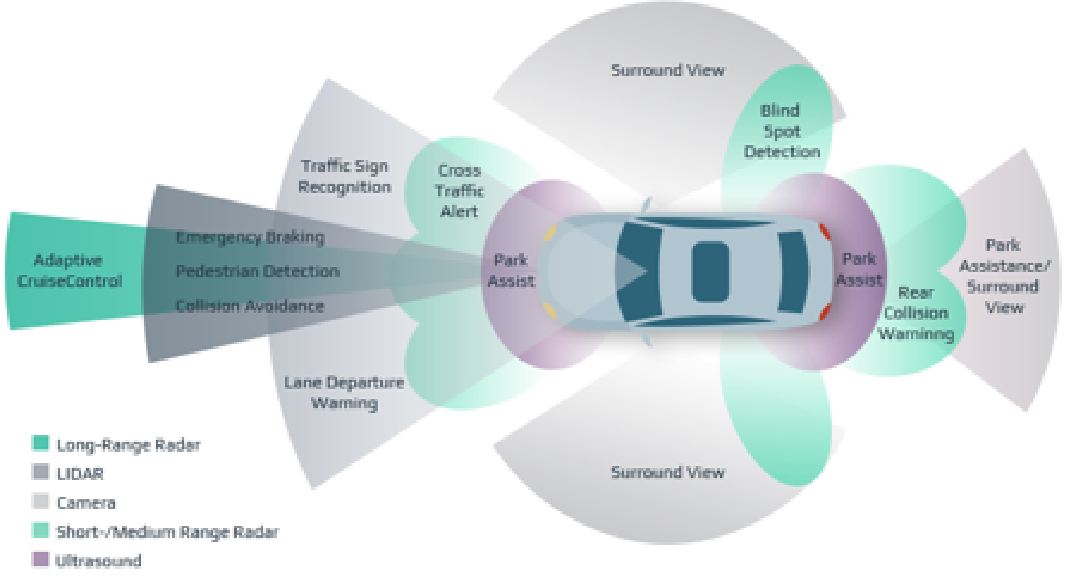
LAPIN AMK
Lapland University of Applied Sciences

Autonomous Driving

- An autonomous vehicle is a vehicle that is capable of sensing its environment and moving with little or no human input. [1]
- SAE's level (Society of Automotive Engineers) [2]
- Combine a variety of sensors:

Radar
cameras
Lidar
GPS
ultrasonic sensors



https://www.intellias.com/sensor-fusion-autonomous-cars-helps-avoid-deaths-road/

Challenges:
- snowy & icy road conditions
- magnetic storms (Aurora Borealis)

Radars and passive radar reflectors could be the key to ***overcome detection problems*** under ***extreme weather conditions.*** (operate in almost all environmental conditions)

BEYOND THE SURFACE

[1] Gehrig, Stefan K.; Stein, Fridtjof J. (1999). Dead reckoning and cartography using stereo vision for an automated car. International Conference on Intelligent Robots and Systems. 3. Kyongju. pp. 1507–1512
[2] https://web.archive.org/web/20170903105244/https://www.sae.org/misc/pdfs/automated_driving.pdf

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Arctic Challenge/ Dr. Chris Händel

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ROADSCANNERS

LAPIN AMK
Lapland University of Applied Sciences

Test Fields

Test field 1: Near Rovaniemi Airport (2018)

- cold and icy conditions (θ < -14°C)

Test field 2: In Muonio (4.3. – 8.3.2019)

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BEYOND THE SURFACE

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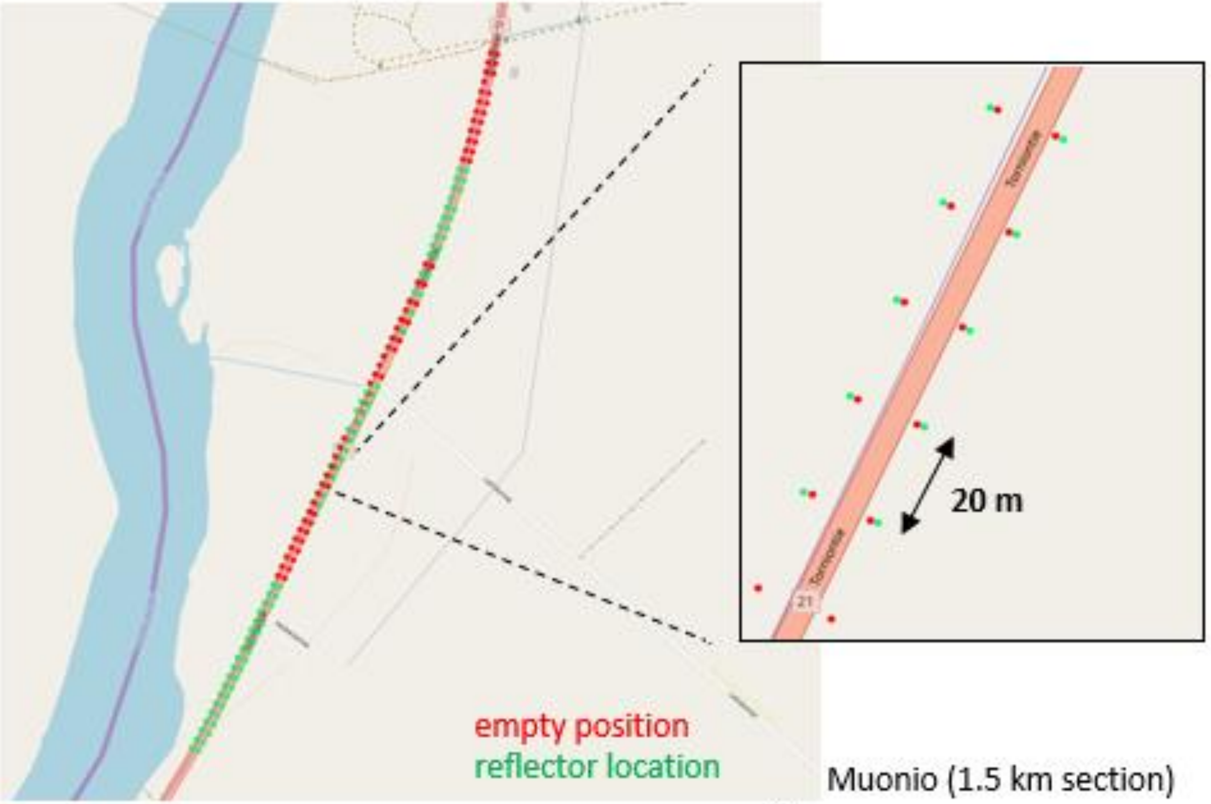
Radar Reflectors

- ***Self-designed*** tubular reflector pole containing three corner reflectors
- 100 pieces were ordered and positioned in Muonio

pole position



Muonio (1.5 km section)

Include up to 3 corner reflectors (Ø 18,4 cm)

Materials and Methods

LAPIN AMK
Lapland University of Applied Sciences

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The Van

1) **Laser 1**

(facing to the ground)

2) **GPS, IMU**

3) **Video** (front/ditch)

4) **Laser 2**

(facing forwards)

5) **Radar system:**

ARS 408-21 sensor
from ***Continental AG***

BEYOND
THE
SURFACE

Summary of the posts and poles field tests

- Influence of Human presence & test field background
- Typical reflector test (reflectors & angle)
- The influence of Snow on radar reflector
- Test field background without reflector poles
- Test filed with reflectors (80 km/h)
- Influence of the driving speed on positioning
- Other vehicles on the test field
- Influence of Blowing snow

Results

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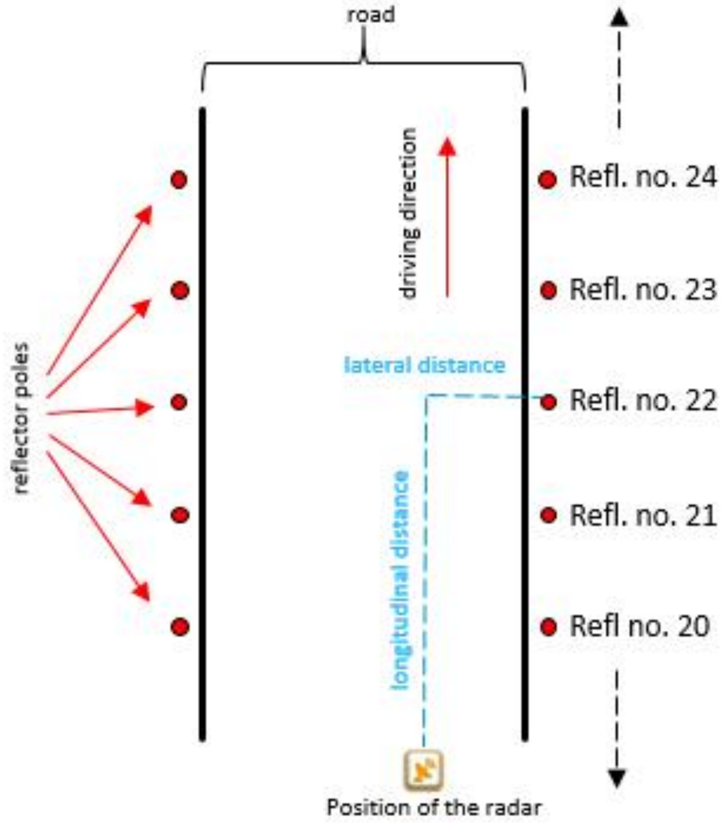
2. The Test Field with Reflectors in Muonio (80 km h^{-1})

- ARS 408-21 sensor from Continental AG



"National Land Survey of Finland" WMS server

Arctic Challenge/ Dr. Chris Händel

BEYOND THE SURFACE

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Summary and Conclusion

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- The **radar from Continental** performed best for our future applications concerning accuracy, resolution, data output and handling.
- **Self-designed Ø20 cm corner reflectors** are a practicable, cheap and easy-to-produce alternative for our purposes to current products on the market.
- The detected signal strength (RCS) depends strongly on the angle between the corner reflector and the radar. Based on this result, we developed a tubular reflector containing three Ø20 cm corner reflectors.
- Self-designed reflectors are **well detectable at 80 km h^{-1}** with all applied methods (camera, radar, Laser Scanner)
- It can be concluded that **pedestrians will not affect the measurements** performed with our setup.
- Typical roadside furniture, such as **lamp poles**, are not practicable as proper radar reflectors for the tested radar systems.
- **Snow** had a very strong influence on the detectability of all tested reflectors. In contrast, **moderate falling snow** did not remarkably affect the detectability of the reflectors.

BEYOND THE SURFACE

1. Posts and poles for guidance and positioning: active

What landmarks, such as delineators and reflective posts, or snow poles and plot access marks, support automated driving? Where should these be located? What should they be like?

SHARPEYE

Material: Pasi Ikonen, SharpeyeSystems, pasi.ikonen@sharpeyesystems.com

Active Poles Guidance – Research Implementation

- Poles
  - 20 poles with active beacon
  - 40m distance between poles
  - Exact position pre-mapped
- Car unit
  - scanning distance 100 / sec
- Measurement technology
  - UWB-IR
  - Cent. Freq 6,5GHz - BW 500MHz
  - Distance Measurement - Time of Flight

SHARPEYE

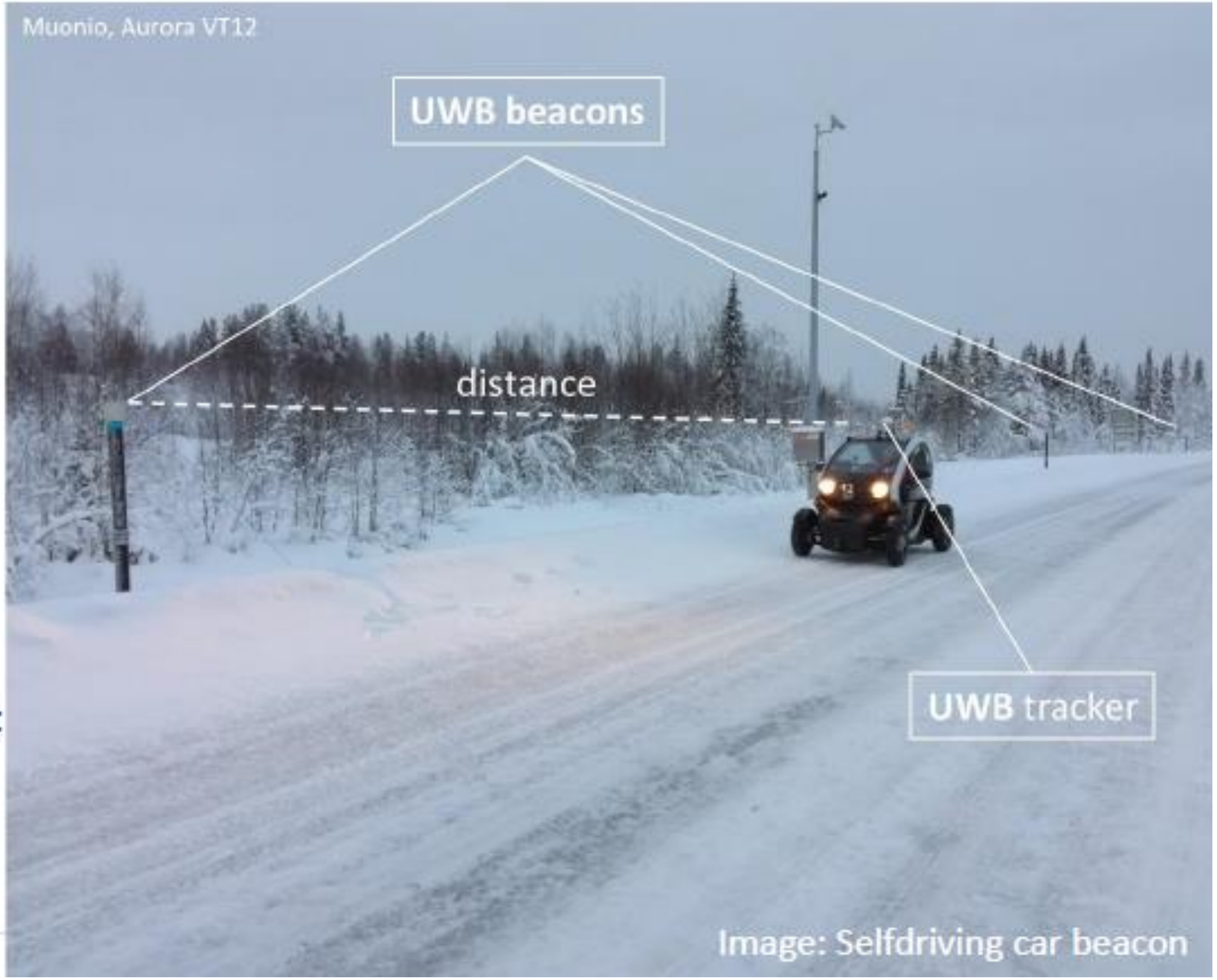
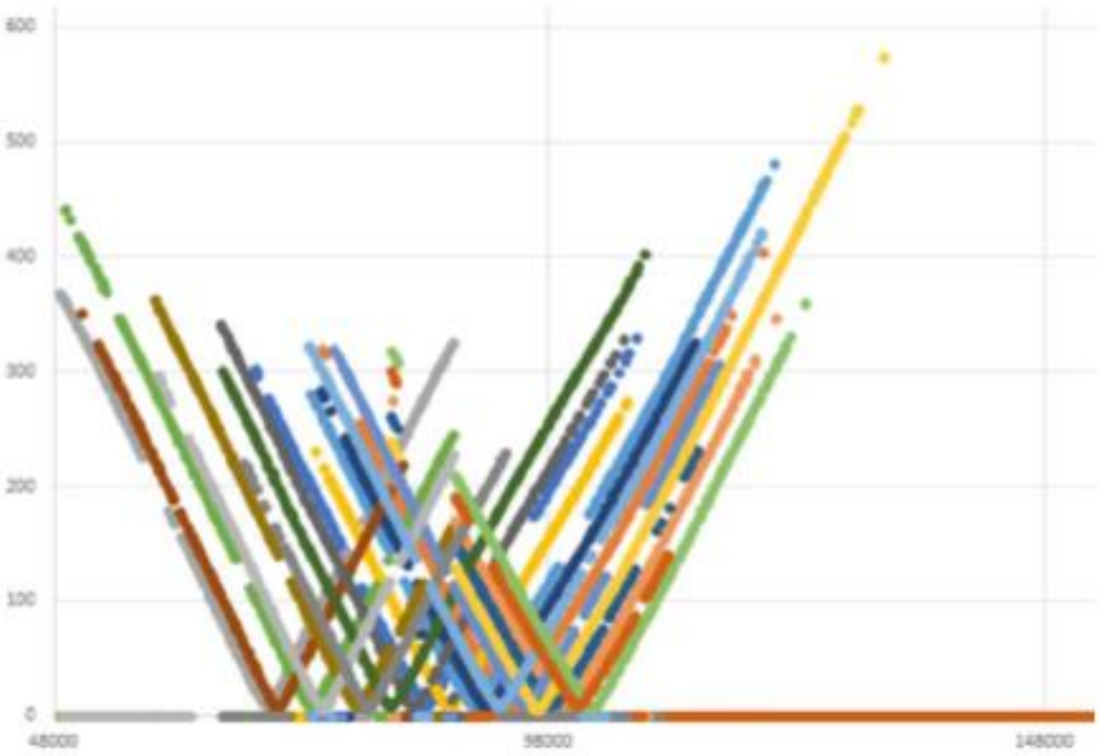


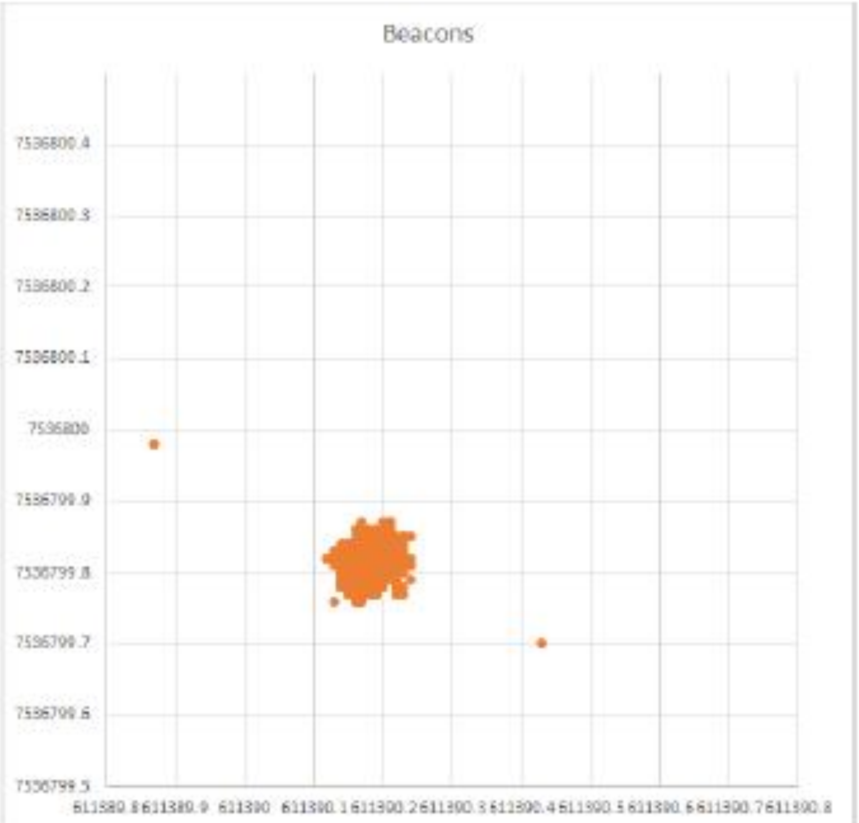
Image: Selfdriving car beacon

RESULTS: Performance of UWB Active Pole System

Driving through road with beacons (Distance and time)



Parked car test. 8k position measurements. The grid is 5 cm



SHARPEYE

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November 25, 2019

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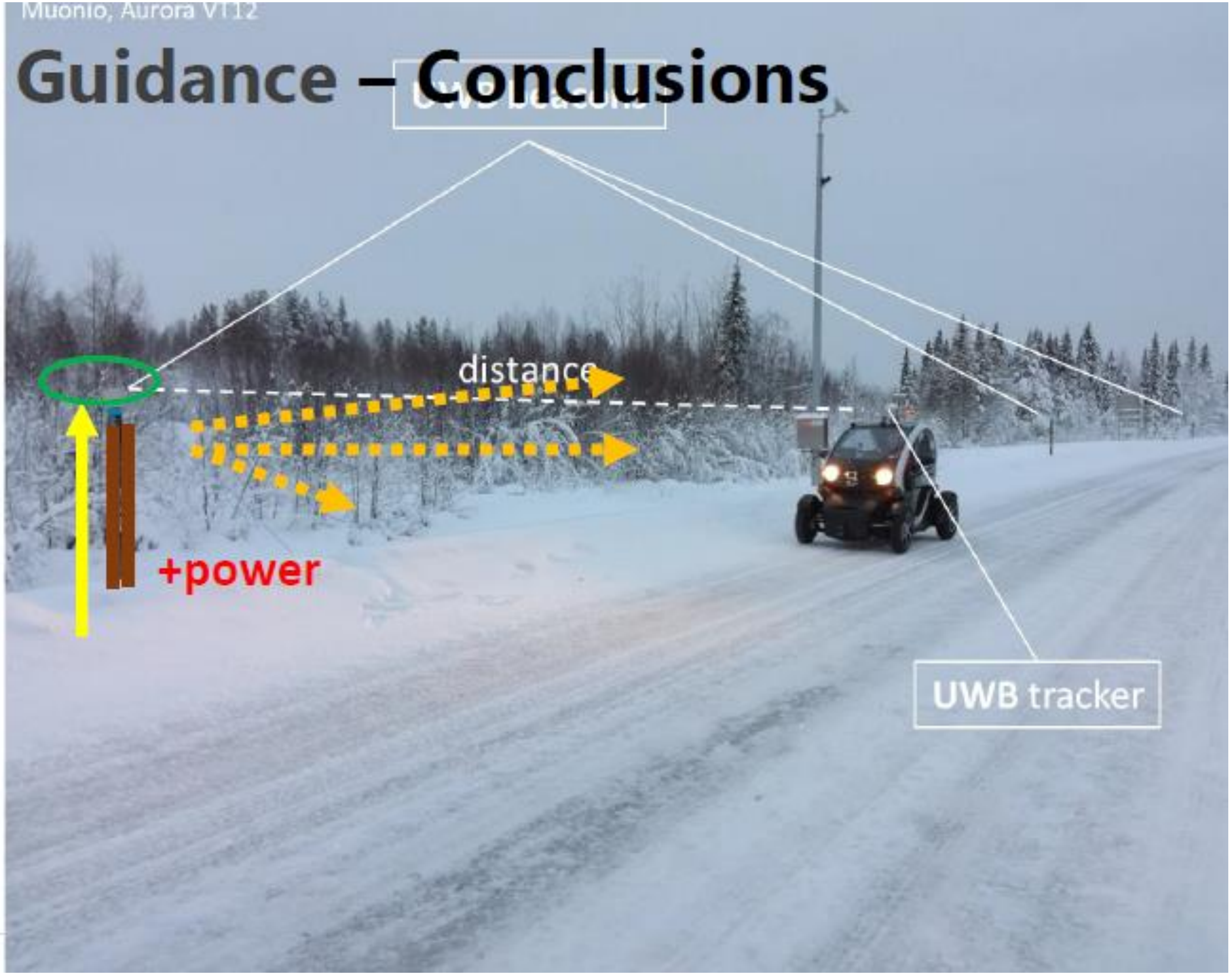
Active Poles Guidance – Results

- **Measurement accuracy**
  - Calculated over a 100.000 measurement the **error or is approximately normally distributed**
  - **with a standard deviation of 27mm**
  - The distance measurement **error is independent of distance**
  - At higher speeds (>55km/h) positioning accuracy was getting worse with the current test setup
  - **This PERFORMANCE is SUFFICIENT for autonomous drive**
- **Measurement range**
  - This tested setup achieved close **to 100 m range (99% reach)**
  - and by improving the setup much **longer ranges can be achieved**
- **Weather**
  - **Weather didn’t affect** UWB range or accuracy based on these tests
  - Tested at temp. 0C – 29C
  - From sunny to heavy snowing conditions

SHARPEYE

Active Poles Guidance – Conclusions

- Line of sight (LoS) visibility to minimum three other poles at the time
- At high enough level a avoid rising level of snow and other obstacles
- 15cm free non radio reflective space around
- Permanent and strong fixing to keep position and avoid violence
- Current UWB needs power of 1W which means:
  - Connection to mains power source
  - Or big rechargeable battery with solar panel .



2. C-ITS hybrid communication

How could the C-ITS Day 1 hybrid services improving traffic flow and safety be implemented on the main road 21 and Highway E8 Aurora Borealis Corridor between Kolari, Finland and Tromso, Norway, and what is their technical operability? What Day 1 services should be implemented in the Aurora Borealis Corridor?

VTT

Material: Risto Öörni, VTT, risto.oorni@vtt.fi

Day 1 –messages and communications technologies

- Day 1 messages
  - Stationary vehicle
  - Road Works Warning
  - Slippery road
  - Animal on the road
- Communication technologies
  - ITS-G5
  - LTE
  - Pre-5G
- Automated vehicle verification








Photos: Risto Öörni and Matti Kutila and Lasse Nykänen

Testfest 2 environment

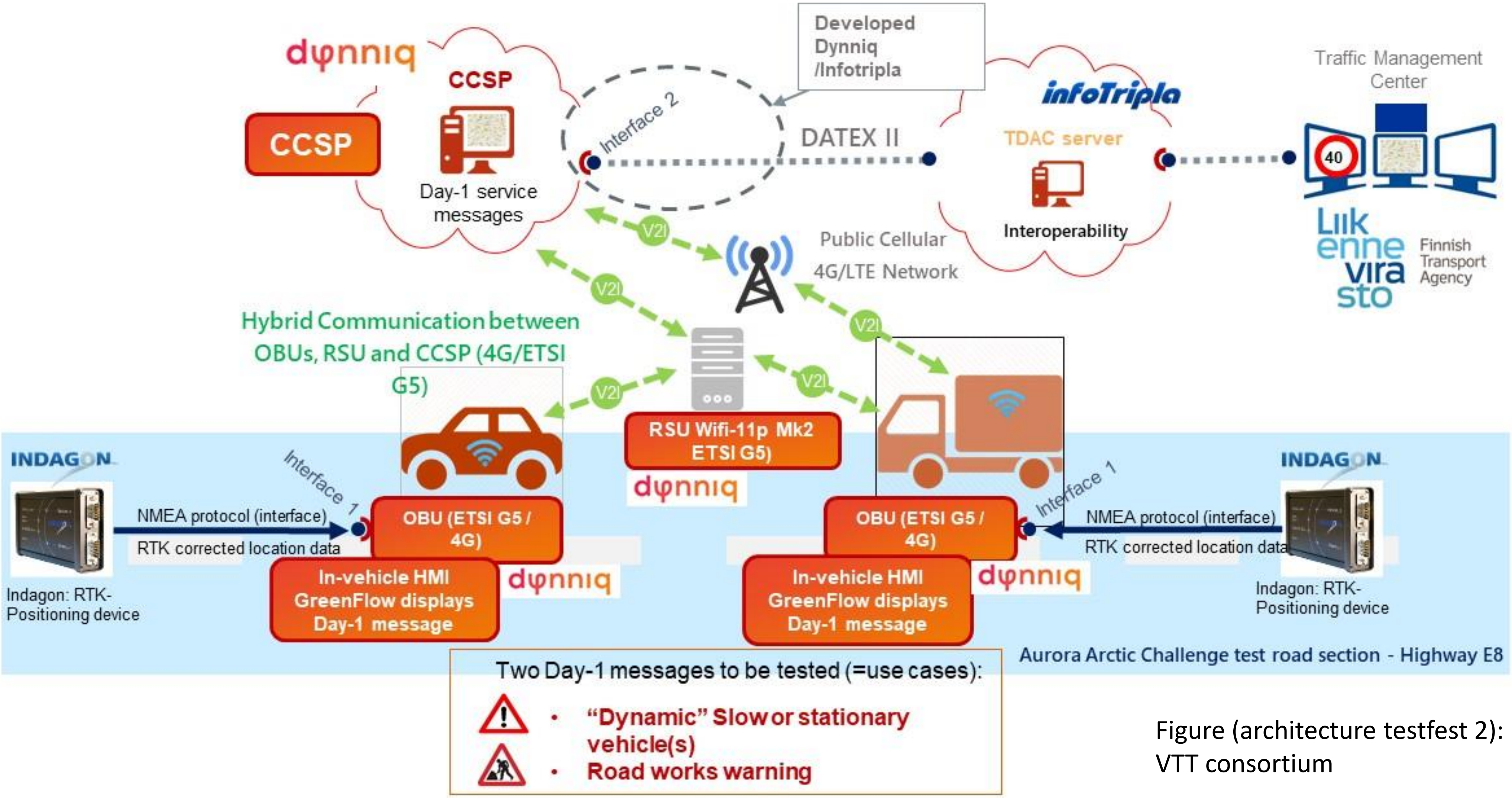


Figure (architecture testfest 2): members of the VTT consortium

Conclusions

- Hybrid communication solution of ITS-G5 and LTE radio communication technologies used for communication of four Day 1 messages of stationary vehicle, animal on the road, slippery road and roadworks warnings, are functional under arctic conditions.
- Transmission of C-ITS messages between several operators is a prerequisite for the implementation of an efficient, internationally compatible system.
- The ETSI ITS-G5 provides better stability but lower coverage than commercial cellular LTE.
- Latency measures difficult due to low N and logging time sync difficulties

3. Communication infrastructure and remote driving

How does the remote control and monitoring of vehicles work in 4G and in the first stage of the 5G network in good/poor weather and road conditions? What minimum requirements should the communications network meet to enable remote control of automated vehicles?

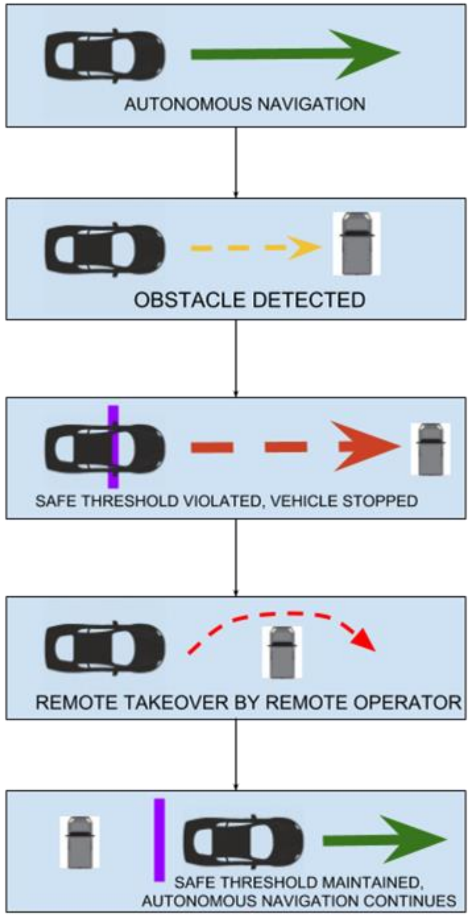
Material: Jussi Suomela, Sensible 4,
jussi.suomela@sensible4.fi

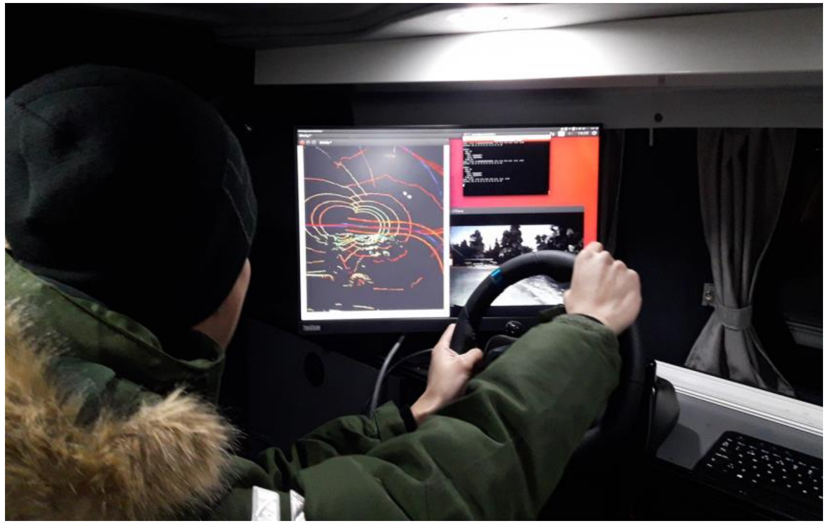
Remote control and experiment overview

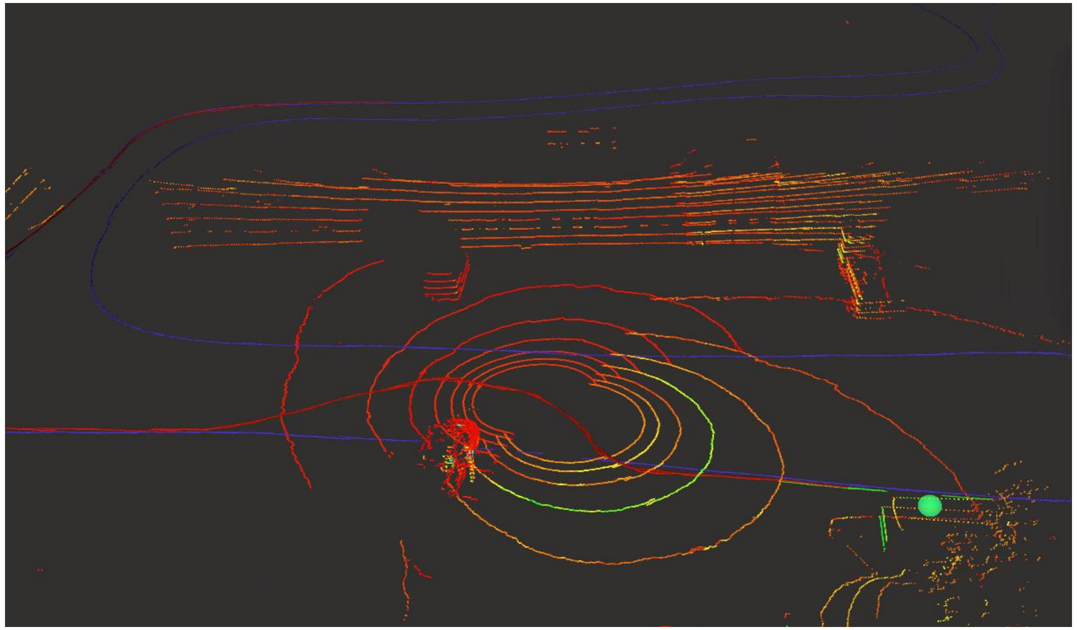
- Automated driving is not always feasible in all conditions.
- In worst-case scenarios, remote control intervention by human operator is required as fail-safe strategy.
- This requires dependable network for communications between vehicle and remote operator.
- In rural location and extreme weather environment this is much more a necessity.

- Part 1: Remote Control-Based Obstacle Avoidance Takeover by Remote Operator (4G / LTE)
- Part 2: 5G Network Analysis in Extreme Weather Environment

Experimental setup and results







5G TEST NETWORK MEASUREMENTS PERFORMANCE EVALUATION

Key Performance Indicators	Description about KPI	Threshold values	Test Results
5G test network overall Linear Performance	Jitter presents average packet delay; therefore, estimated threshold jitter value (Cisco) is expected to balance the operation.	30 ms	5.20 ms
5 G test Network average throughput	Average throughput is a good KPI to analyze the performance of 5G test network by comparing it with a threshold value	5 Mbps	2.4 Mbps
5G test network Service availability on Test track	Service availability is another good KPI by analyzing the availability of network coverage on FMI test track	90 % service availability during each lap.	88 %

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SUMMARY

- Remote Intervention by Remote Human Operator is a safety requirement for AV in edge cases scenarios.
- 4G/LTE network is not sufficient for video streaming due to the network latency issue.
- It is obvious that 5G is the emerging solution for this case.
- 5G real network will focus on very high data rates with very low latency, praiseworthy user experiences in densely populated areas, vehicular communication, proficient management of several devices and reliability.

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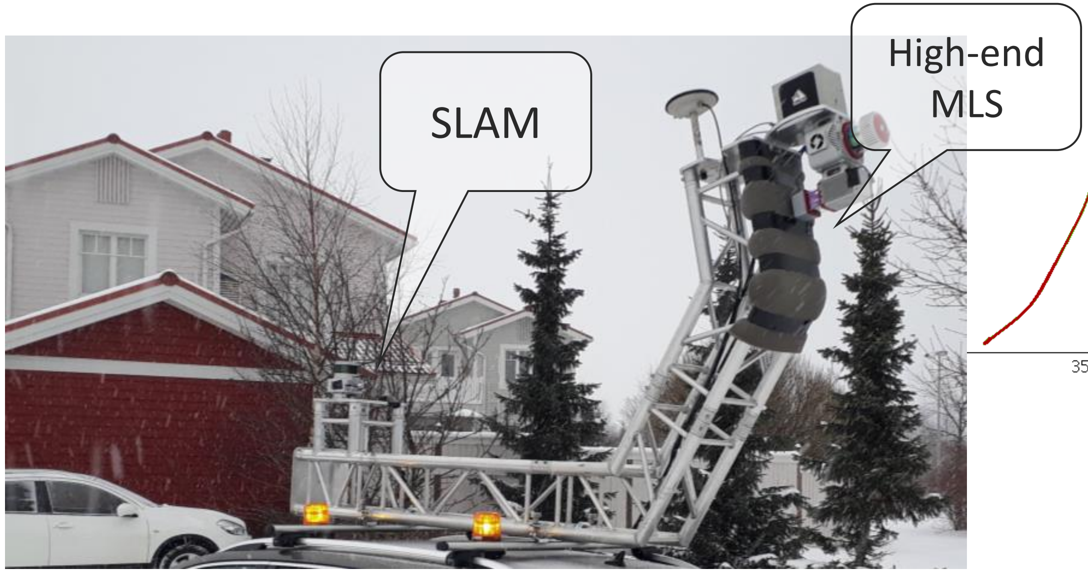
4. Positioning of vehicle

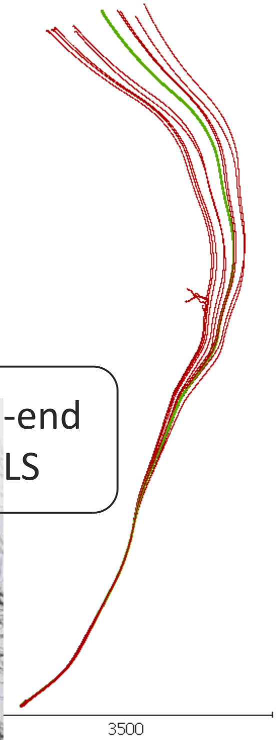
In what way and how accurately could a vehicle be positioned to fulfil the needs of automated driving at northern latitudes where no edge markings or roads can be recognised? How can different methods be applied to special locations and situations, such as blind spots or glare?

Material: Umar Zakir Abdul Hamid, Sensible 4, umar.hamid@sensible4.fi
Juha Hyyppä, Solid Potato

Tested techniques

- Simultaneous Location and Mapping SLAM (relative positioning)
  - Low-end laser scanner as positioning device (Velodyne VLP-16)
- Pointcloud-to-pointcloud matching (HD) (absolute positioning)
  - Detailed high-accuracy pointcloud as HD map (high-end mobile laser scanner)





Outcomes

- Typical accuracy for **vehicle positioning was 20-30 cm based on our integrated SLAM and HD map matching** approach (5 sec data), which was implemented to give an upper bound error for autonomous vehicle localization, varied between 5 and 50 cm mainly based on the availability of the number of features in the surrounding.
- Consequently, the increase of the number of objects feasible for point cloud matching, such as the snow sticks used to guide the snow plough, are a good way to improve the positional accuracy of autonomous cars in an easy manner.
- Rock cuts provided best results (even when collected during winter in consecutive days)
- In reality, SLAM+IMU+GNSS+HD+other techniques are integrated taking into account

TEST VEHICLE (SENSIBLE 4)

Juto

- Sensible 4 Autonomous Vehicle Prototype Test Rig.
- Equipped with drive by wire.
- Installed with required sensors such as 3D-lidars, radars for positioning and obstacle detection.
- More details can be found at http://sensible4.fi/technology

WORK OVERVIEW

GNSS POSITIONING

AUTONOMOUS SLAM (SOLID POTATO)

HD-MAP BASED (SOLID POTATO)

LIDAR-BASED POSITIONING

FOUR SCENARIOS

Two maps generated:

- Normal condition and after snow-storm

Positioning test using combination:

- Using "clear map", test positioning in clear weather and in snowy weather.
- Using snow map, test positioning in non-snow environment and in snow environment

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PERFORMANCE SUMMARY Y-AXIS (LATERAL DIRECTION)

NON-SNOW DRIVING USING NON-SNOW MAPS

Average Error (Relative Position of Vehicle) 0.187 m	0.187 m

SNOW DRIVING USING NON-SNOW MAPS

Average Error (Relative Position of Vehicle)	0.105 m

NON-SNOW DRIVING USING SNOW MAPS

Average Error (Relative Position of Vehicle)	0.166m

SNOW DRIVING USING SNOW MAPS

Average Error (Relative Position of Vehicle)	0.117 m

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SUMMARY

- RTK-GNSS-based positioning possesses 'no-Fix' RTK-GNSS scenario.
- HD-Based Positioning yields dependable positioning solution for AV, and does not require any additional infrastructure-related systems.
- The solution used by Sensible 4, a combination of the multiple sensors as well as non-linear algorithms with the satellite information yield a reliable positioning performance of an AV vehicle, even in rural Arctic conditions, with the maximum lateral error of 0.187 m in all conditions using a single map.
- Research should be performed to develop a wider geofencing region for HD maps with large-scale test fleets and longer durations.
- At the same time, a lot of effort is also directed at sensor development, which should go hand-in-hand with software development.

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Final report link:
https://julkaisut.vayla.fi/pdf12/vt_2019-19_arctic_challenge_web.pdf

Thank you!